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**Annual Project Summary**  
**RIDGETOP SPLITTING, SPREADING, AND SHATTERING RELATED TO**  
**EARTHQUAKES IN SOUTHERN CALIFORNIA**

Contract 99HQGR0042

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Program Element II: Evaluate Urban Hazard and Risk.

**Investigations Undertaken**

During May 1998 we mapped ridgetop troughs and scarps on the mountains north of the Los Angeles Basin, to identify landforms and sediment traps likely formed by strong earthquake shaking and subsequent ridge collapse (sackungen). The results of this mapping are contained in our Final Technical Report for FY 1998 for NEHRP contract 98-HQ-GR-1026 (McCalpin and Hart, 1999). In 1999 we excavated three trenches across linear troughs on ridgetops in the northern and western San Gabriel Mountains.

During October 1999 we spent 2.5 weeks excavating, logging, and sampling three trenches across ridgetop collapse landforms. The sites were: 1) summit of Blue Ridge directly south of Wrightwood, 2) summit of Upper Lytle Creek Ridge directly south of the Sharpless Ranch, and 3) summit of the ridge about 1 km east of Kagel Mountain, southeast of Pacoima Reservoir (Fig. 1).

The goal of this trenching investigation was to describe, for the first time in southern California, the structure and stratigraphy beneath these troughs and scarps, and to see if they indicated whether the troughs were formed by slow creep (Zischinsky, 1966, 1969; Tabor, 1971; Radbruch-Hall et al., 1976, 1977; Radbruch-Hall, 1978; Varnes et al., 1989) or by sudden vertical displacements, as observed after several California earthquakes elsewhere (Hart et al., 1990; McCrink, 1995; Nolan and Weber, 1992; Ponti and Wells, 1991; Spittler and Harp, 1990; Technical Advisory Group, 1991; Harp and Jibson, 1996). If the latter, we wished to apply standard paleoseismic techniques developed for active normal faults to determine the amount and

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timing of the displacement event(s). The timing of these events, as dated by radiocarbon, would then be compared to the known paleoseismic histories of area faults to see if they coincided. If they did coincide, we would conclude that these ridge-top "sackugen" were probably formed by ridge crest collapse during severe earthquake shaking. Such a conclusion would mean that sackung troughs could be added to the suite of secondary paleoseismic evidence (as defined by McCalpin and Nelson, 1996). Such an addition would have worldwide implications, particularly in areas where seismogenic faults do not create surface fault scarps, such as in active fold and thrust belts.

Conversely, if the dates of sackung displacement events fall between those of any known paleoseismic fault history, it implies either that: 1) severe shaking is not the cause of these troughs, or 2) the troughs were created by shaking from a fault that does not yet have a known paleoseismic history. In the Los Angeles Basin such a fault could be a blind thrust, such as the Hollywood fault (Dolan et al, 1997) or the causative fault of the 1994 Northridge earthquake. In that case, presumably future paleoseismic studies on the blind thrusts might some day date these same events, using techniques that have not yet been developed.

## Results

Two of the three trenched ridgecrest troughs were the surface expressions of half-grabens with moderately dipping ( $45^{\circ}$ - $65^{\circ}$ ) normal faults, whereas the third trough was underlain by a more symmetrical graben. The higher and steeper scarp on the surface did not necessarily overlie the master fault. In fact, at all three sites the higher surface scarp was developed on the hinged side of the graben, whereas the scarp atop the master fault was smaller but steeper. The 1-3 m of unconsolidated Holocene (?) slopewash beneath each trough was relatively coarse-grained (sand and gravelly sand) and poorly stratified. Accordingly, the main contacts mapped in these deposits were soil horizon boundaries. In places it was difficult to distinguish whether changes in color and texture were parent material contacts or soil horizon contacts.

The lower boundary of slopewash was gradational with weathered bedrock. The bedrock beneath the troughs was either extensively shattered (which we defined as "exploded bedrock") or chemically weathered from infiltration of water beneath the closed depression, much more so than beneath the flanking scarps.

Each trench exhibited stratigraphic evidence for 2-4 displacement events, but not all events could be tightly dated. In the Blue Ridge (Fig. 2) and Upper Lytle Creek Ridge (Fig. 3) trenches, the latest deformation event occurred after 790-867 cal yr. BP but before 285-300 cal yr. BP. This time span overlaps the age ranges of three dated paleoearthquakes on the San Andreas fault at the Wrightwood paleoseismic site of Fumal et al. (1993), only a few km west of the Blue Ridge trench. Thus, the dating constraints from the sackung trenches, due to the dispersed nature of soil organics and charcoal, are not tight enough to make a positive correlation with any particular paleoearthquake on the San Andreas fault. The older displacement events at Blue Ridge and Upper Lytle Creek Ridge are generally older than the oldest dated event in the Wrightwood or Pallet Creek chronologies.

The latest displacement event at the Kagel Mountain site (Fig. 4) is relatively well bracketed between 1830 and 2355 cal yr. BP. This age range barely overlaps with the age range

of the latest paleoearthquake on the San Gabriel fault, the closest active fault to the site, as dated by Cotton et al between 907 and 1993 cal. yr BP.

We have demonstrated that sacking troughs contain a stratigraphic record of repeated displacement events that can be dated. However, given the type and distribution of carbon in the trough deposits, it will require 2-3 times as many radiocarbon dates as we had budgeted for to bracket event dates well enough to compare them with paleoearthquake chronologies from trench studies.

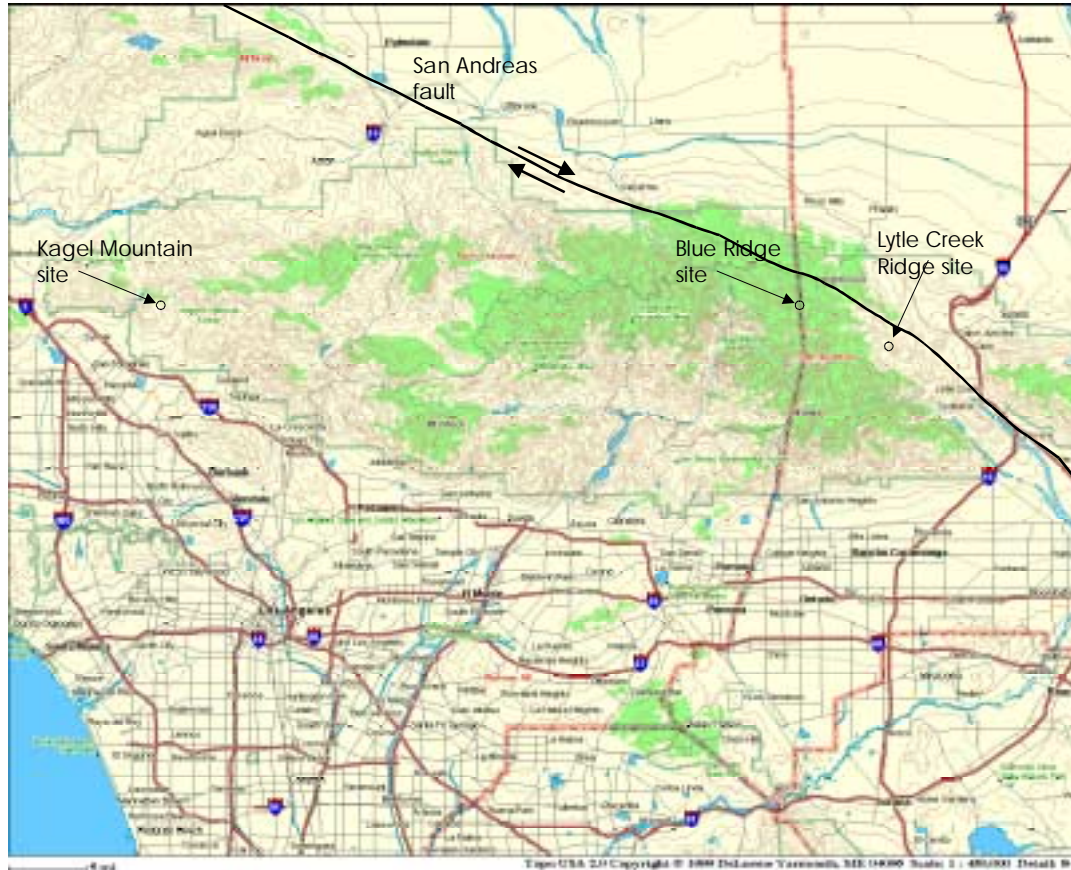


Fig. 1. Location map showing sites of all three trench investigations across sackungs, preformed in Oct. 1999.

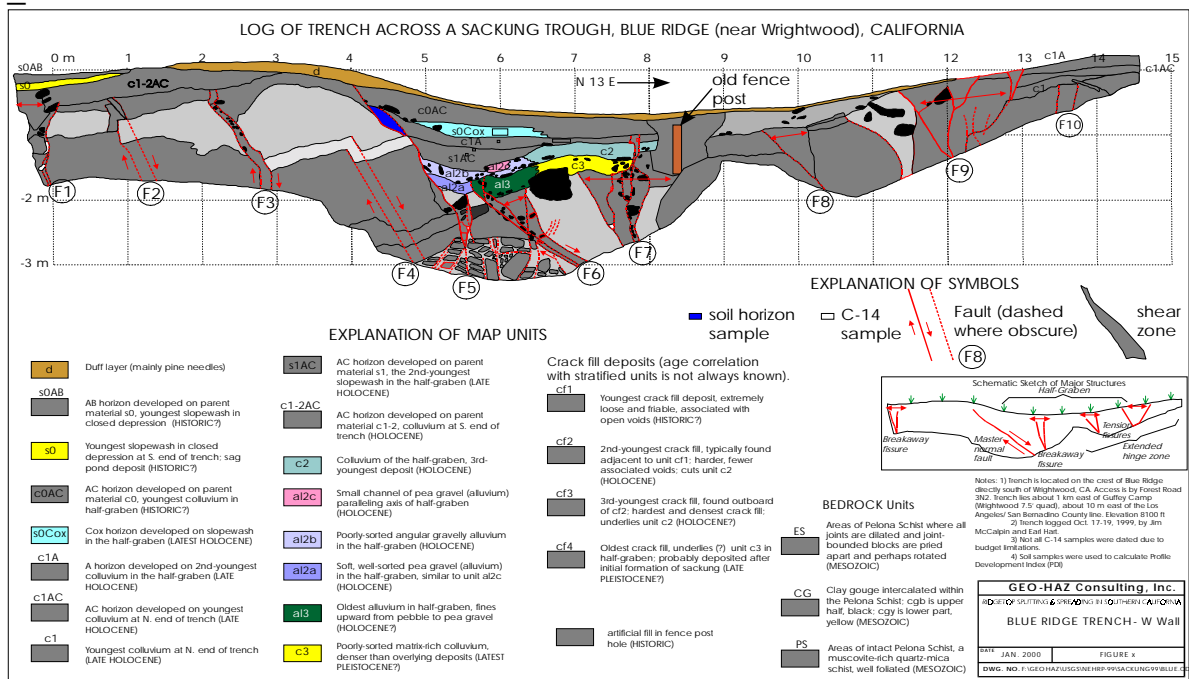


Fig. 2. Log of the Blue Ridge trench.

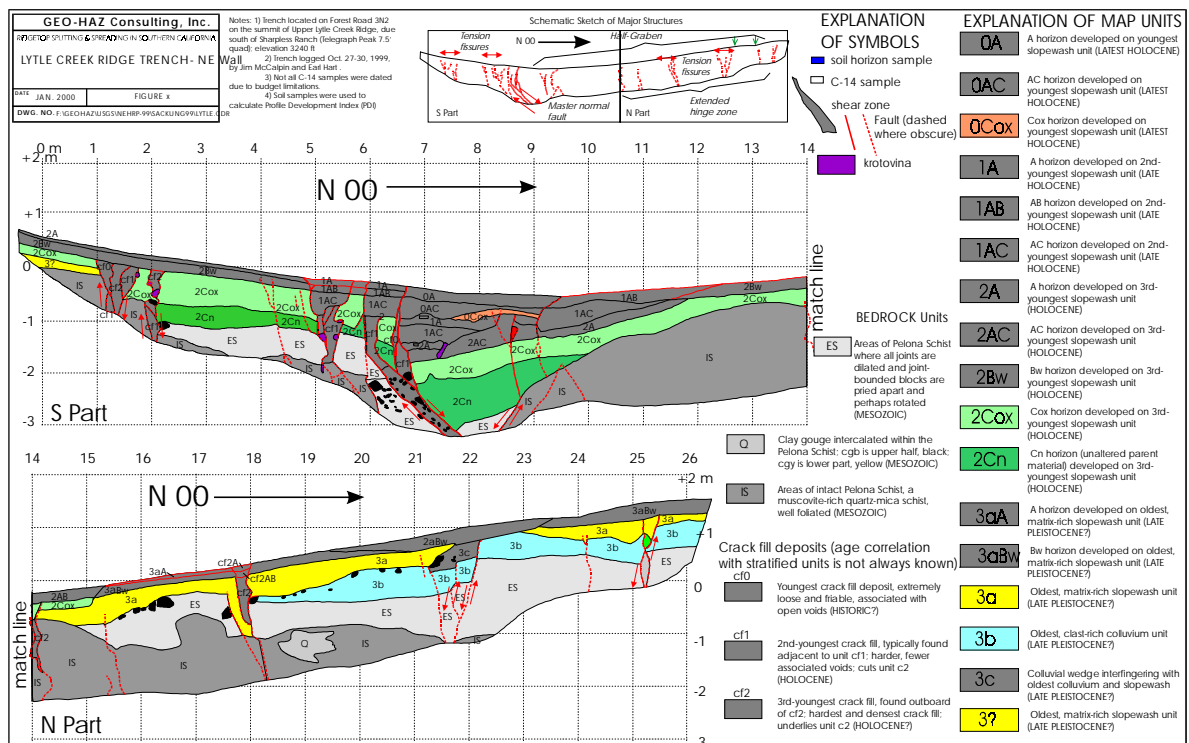


Fig 3. Log of the Upper Lytle Creek Ridge trench.

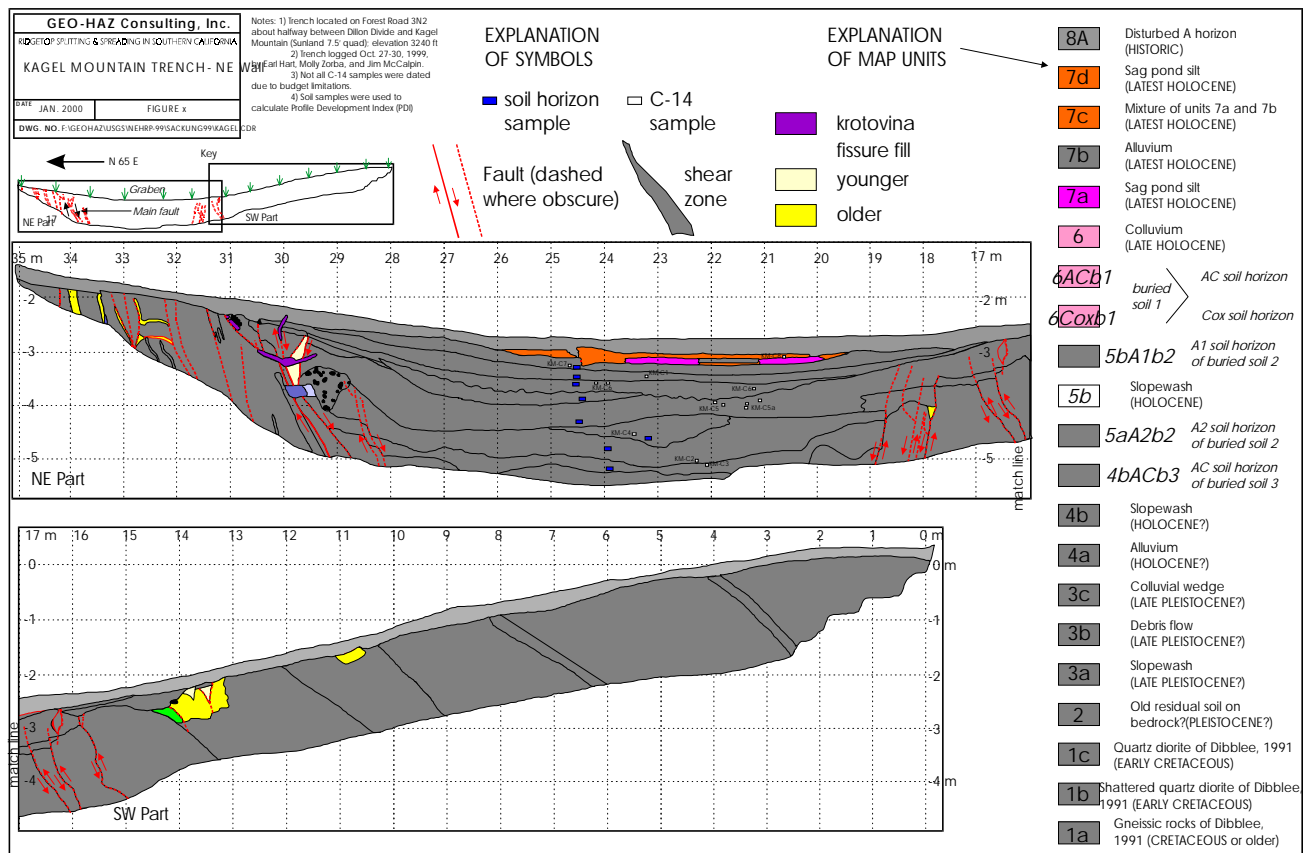


Fig. 4. Log of the Kagel Mountain trench.

## CONCLUSIONS

1) Trenching at each of the three sites demonstrates that repeated ground rupture occurs along ridgetop depressions. That these anomalous ridgetop depressions are formed by ground rupture during large earthquakes has been demonstrated after the 1989 Loma Prieta earthquake (Hart et al., 1990; Spittler and Harp, 1990; Ponti and Wells, 1991) and other earthquakes. That earthquakes caused the anomalous ridgetop depressions has not been conclusively demonstrated by our study, but all of the most recent events at each of the trench sites are consistent with known paleoearthquakes on nearby active faults.

2) Our trenching clearly demonstrates that repeated ruptures coincided with existing scarps that define ridgetop depressions. As much as a meter or more of vertical displacement can occur during these rupture events. The observed ruptures penetrate bedrock and are similar to tectonic rupture along normal faults. Because these rupture events are equivalent in frequency (2-4 events in ca. 10,000 years) and magnitude to ruptures on normal faults in California, ridgetop depressions and scarps pose a hazard to structures that may be sited on ridgetops and should be

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evaluated and avoided as if they were tectonic faults. CDMG may wish to consider zoning these features, perhaps as part of its Seismic Hazards Zoning program since these fault-like features appear to be incipient landslide features.

3) Based on our previous study (McCalpin and Hart, 1999), the anomalous ridgetop depressions appear to form a continuum with landslides and to have the same causal mechanisms.

4) Not all deformation events may have been recognized, especially smaller events that mainly produced fissuring.

## 8. RECOMMENDATIONS

Although we have demonstrated that sackung troughs contain a stratigraphic record of repeated displacement events that can be dated, we fell short of our goal of making a one-to-one match of sackung displacement events with dated paleoearthquakes. In hindsight, it was naive for us to think that we could compare our sackung chronologies, based on one limiting C-14 date per event, with paleoearthquake chronologies supported by many C-14 dates per event. We recommend that additional trenching studies of ridgetop depressions, supported by larger dating budgets more like those of fault trenching studies, would decrease the uncertainty in dating sackung events, and make a better event-to-paleoearthquake correlation possible. As a guess, it will probably require 2-3 times as many radiocarbon dates as we had budgeted for to bracket event dates well enough to compare them with paleoearthquake chronologies from trench studies.